UNRAVELING THE MYSTERY OF GPS (GLOBAL POSITIONING SYSTEM)

By Roger Chappell
Technology Integration Engineer

Does one size fit all? What is the difference between the $99 unit in the sporting goods store and the one a surveyor uses? There seems to be a lot of confusion today about GPS units. And rightly so, with prices ranging from $99 to over $40,000. I get asked these questions a lot.

In this on going series, I hope to answer these questions, and to help demystify this strange new technology. The military, surveyors and other select groups have been using this technology for a long time, but it has only been the last couple of years that the common person could afford to use it. It reminds me of the explosion in popularity of desktop PCs in the last 20 years. What was shrouded in mystery a mere 20 years ago is now a part of our lives, and in many of our homes. The big exception this time is, that there are more players in the game now than Apple and Big Blue.

Will the next 20 years find geospatial coordinates as common as email is today? Probably not, but hopefully it will be as easy to use. Along with looking at GPS, we will look at various peripherals like laser range finders, voice command, digital cameras, dead reckoning systems, and how these tools function together. We will also look at software systems, databases, and how to use your data in an GIS (Geographic Information System) environment.

Before we can begin to answer the question "What type of unit is best for you?" Let us take a quick look at some of the different types of units available.
I generally divide them into four types of systems:
· The first one we will call "Navigation grade" receivers.
· The second type we will call "Mapping grade" receivers.
· The third type we will call "Survey grade" receivers.
· The fourth type we will call "Specialty and Military grade" receivers.

Navigation grade receivers:
These units typically are not DGPS (Differential Global Positioning System) capable. We will discuss things that affect positional accuracy later on but, in general, any unit that does not use DGPS can only pinpoint a location within a 100 meter circle. Once you are in that 100 meter circle, you will only be paying for the added features of the unit. These units should be in the under - $1000 range, and most of them under $500 depending on the features.
Some include things like maps, data points or line feature storage, and even satellite email messaging.

Mapping grade receivers:
These units should be DGPS capable, and should be capable of 5 meter to "sub - meter" (smaller then a 1 meter circle) positional accuracy. These systems range from over a $1000 to as high as $30,000 depending on the features, software, and peripherals included with the system. Most of these units come with a computer system and software that allows the user to input various types of data. Some systems include laser range finders, digital cameras, dead reckoning systems, voice command and every type of test probe and meter imaginable.

Survey grade receivers:
These are DGPS capable, and should be capable of centimeter accuracy or better. These units range from $5000 to $40,000 per unit. Achievement of centimeter accuracy requires skill and training and is best left to the GPS guru types for now. For example, there are RTK (Real Time Kinematic) systems that require a base

station to be set up over a survey marker of known coordinates. There are radio links that must be maintained, and the data still must be corrected and verified.
As part of this series I plan to dedicate several of the articles to addressing some of the more complex issues involved with achieving this type of accuracy, and hopefully to some extent demystifying it as well.

Specialty and Military grade receivers:
This is a general "catch all" category. The price and accuracy can vary dramatically. I throw this category in so we have a place to discuss things such as Specialty receivers used for Aerial photography, underwater positioning, and the like.
Also Military P(Y) Code Receivers, that utilize the encrypted P code from the GPS satellites. These recievers are only available to the military and some federal agencies. Receivers that aren’t Military Receivers are called C/A (Civilian Access or Course Acquisition) code receivers. The P coded receivers remove the effects of SA (Selective Availability), but may not compensate for ionosphereic, atmospheric or other conditions. Even without SA, these receivers are only accurate to between 3-9 meters (without differential correction).

So what is SA (Selective Availability)? The greatly simplified version is this:
The DOD (Department of Defense) controls the GPS satellite system. Each satellite has a very accurate atomic clock, that broadcasts the current time, and your receiver also has a clock built into it. Your receivers clock is not atomic, but it should be pretty good. The better the clock, the better the accuracy. By comparing the time from the GPS satellites (when it left space), when it got to you (the clock in your receiver), and knowing that the signal travels at a constant velocity (the speed of light), it is then simple math for the computer in your receiver to figure out how far away that satellite is from you. I don’t know why they use the speed of light instead of the speed of dark, I’m just glad I don’t have to do the math.
Anyway, it takes the signal from three or more satellites to triangulate a position in space (3 satellites for an X,Y position, 4 or more to add Z). This is called trilateration. Everything about the process comes down to time and velocity.
Here’s where the mystery comes in. There are invisible forces acting on these signals that change the velocity (ionosphereic and atmospheric) or time (clock errors or human intervention). In theory, if you had an atomic clock in the vacuum of space with no interference, the measurements could be perfect.
Even though the satellites are way up there (12,600 miles), it is pretty much "line of sight." Unlike radio waves that you can pick up accurately (with no static) inside a building; even interference as minor as leaves on a tree can stop the signal from reaching you. I’ve have had people demonstrate that their equipment can pick up satellites even in a building. What they are seeing is known as "multi-path" or reflection. These multi-path signals have reflected off something. This means that the signal has taken a longer (time and distance) to get from the satellite to your receiver. This distorts the positional accuracy of the readings. Remember, time related to distance, and at the speed of light it doesn’t take much added time to really mess up your distance.
So back to SA. Since DOD controls this system, they also control the accuracy of it by controlling the time that is output from the satellites. This system was created and is operated by the DOD for military purposes. Besides wanting to know where in the world things are, it is used for military targeting, and it is not a good idea for everyone in the world to have that pin point targeting ability. So they play with the time element a little bit. This also makes it a lot harder for someone on the ground to target a satellite, especially if it is moving and dodging in a virtual hundred meter circle.

Where does that leave the C/A code receiver people? I say, "in great shape." We didn’t have to install and maintain the system, or pay rental on all these free signals from space. We can use them for free, provided we have the right equipment. The DOD gives us free access to accuracy that is within a 100 meter circle, 95% of the time, and most of the time the circle is much smaller than 100 meters. That is good enough for most hikers, hunters, boaters and general purpose navigation. Even better news is that in March 1996, President Clinton approved the phasing out of SA over a 10 year period. In theory your cheap navigation receiver will get more accurate as time goes on. This will help the navigation people immensely.
The bad news is, that it still won’t correct all possible inaccuracies. If you want sub-meter you will still need

DGPS.

The last question we will briefly cover in this issue is, what is DGPS, and how does the D (Differential) in DGPS help you?
In a nutshell, DGPS is achieved by using two receivers. The first receiver is the one you bought to do your field work with. The second receiver may be a base station, DGPS vendor, or even a unit that you have set up yourself. Whatever the case is, the second GPS receiver is placed over a point with a known coordinate value (such as a survey marker). Now that the receiver is at a known coordinate value, you can compare the signals that it is receiving against the coordinates that it is at. The difference in distance between the receiver and the point projected by the GPS signal is your correction factor. From a very simplified view: if the signal coming into the GPS receiver determines that its location is 50’ to the west and 25’ to the north, of where my "known coordinates" say the receiver should be, then I need to subtract that distance from my measurements made in the field. Then it is just a matter of comparing the position that you receive in the field with the corrected ones from the base station and doing a little math. Again, thank goodness for computers and software. This is provided that the receiver in the field is looking at the same satellites that my base station is using. Some vendors use a network of base stations and adjust over long distances (baselines), then broadcast their corrections through a satellite to you.

There are two main ways that differential correction is accomplished, one is "post processing," the other is "real time."
Post Processing:
In this scenario, the base station stores raw GPS positional fixes and software is used to compare the raw positions to the coordinate value of the receiver. This data is then placed in a log file or database and distributed. If you are using someone else’s base station, keep in mind that there are various formats and positional fix rates that are collected. You will have to determine if their data will meet your needs. Look for the "meta data," this is the data about the site, base station, and data that you are wanting to use. Then you will need to get the files you need to use to do the differential correction. Some base station information can be accessed directly over the Net, some you may have to contact the base station operator. Now that you have the base station files in hand, it is simply a matter of figuring out the software you bought that compares the two.

If you are new to GPS, it is a good practice to visit survey monuments as often as you can when collecting data in the field. This is a point with known coordinate values, and I like to verify my data against known points whenever possible.

Real time:
Real time "Differential or correction," is not to be confused with "Survey Grade" Real Time Kinematic (RTK systems). Using real time differential correction is basically the same concept as stated above in the post processing section. The big difference is that your field receiver is in constant contact with a base station, through radio or satellite links, making the differential corrections on the fly in "real time." Some equipment even allows you to do both "real time" and "post processing" differential correction on the same data.

There are free broadcast corrections available in many locations (CORS stations), and there are companies that sell these services as well. It is up to you to find the system that works best for you.

I hope this gives some of you a starting point for answering the question "what type of unit is the best one for the job?" Any of the above systems will tell you where in the world you are, and some will even tell others what you found when you got there. Sometimes you may pay a heavy price to get the features and accuracy that you want. Some units will give you great accuracy and some will do it with great complexity, but as with any technology, it is getting smaller and easier to use everyday.

For past issues of the T2 Bulletin:
http://www.wsdot.wa.gov/TA/T2Center/T2Bulletin-archives/T2Bulletin.html

This page was revised on: 8/6/01